

Crackability and chemical composition of pre-treated cashew nuts using a hand-operated knife cutter

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Abstract: The crackability and chemical composition of pre-treated cashew nuts were investigated considering three nut grades (large, medium and small) and two methods of pre-shelling treatment (hot-oil roasting and steam-boiling). The pre-treated nuts were shelled using a hand operated knife cutter. Crackability was calculated as a ratio of the weight of completely shelled nuts to the total weight of nuts fed into the machine. Whole kernels out-turn was calculated as the ratio of the weight of whole kernels to the total weight of kernels recovered after shelling. Chemical analyses were carried out following standard methods in literatures. The average values of crackability for raw, roasted and steam-boiled nuts were 76%, 100% and 99% respectively. For roasted nuts, crackability was higher than that of steam-boiled nuts and pre-shelling treatments affected whole kernels out-turn significantly ($p<0.05$). Large and medium roasted nuts exhibited the highest whole kernels out-turn (99.6% and 99.5% respectively). Raw nuts gave the least values of whole kernels out-turn (62%, 33.9%, and 44.7% for large, medium and small respectively). Pre-shelling treatment made cashew nuts more amenable to fracture; but the whole kernels out-turn of large nuts was generally higher than that of medium and small nuts. The pre-treatments showed no significant difference in the chemical composition and energy content of cashew kernels; but for crude fiber and carbohydrates wherein the differences were significant ($p<0.05$).

Keywords: cashew nut, pre-shelling treatment, crackability, whole kernels, chemical composition

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1 Introduction

Cashew nut (*Anacardium occidentale*) provides a nutritious kernel and serves as an ingredient for confectionery and baked food products (Azam-Ali and Judge, 2001; Andrighetti et al., 1994; Ohler, 1979; Agnoloni and Giuliani, 1977). With about 46 g of crude fat (about 74% of which is oleic acid), 25 g of carbohydrate, 21 g of protein and 596 kcal of energy per 100 g of intake; cashew kernel is rich in essential amino acids and minerals which are seldom found in daily diets (Holland et al., 1991; Davis, 1999). The removal of cashew kernel from the shell is a labour intensive operation involving cleaning/grading, pre-treatment by

roasting or steam-boiling, shelling, separation, drying, and peeling (Agnoloni and Giuliani, 1977; Ohler, 1979; Andrighetti et al., 1994; Azam-Ali and Judge, 2001; Balasubramanian, 2006). The peculiar curvature of the nuts, the corrosive oil in its mesocarp and brittleness of the kernel make cashew nut shelling tedious; the greatest difficulty is the removal of the tough outer shell without damaging the encased kernel.

Traditional cashew nut shelling involves placing individual nut on a flat stone and applying repeated impact with a wooden mallet along the vertical and horizontal axis (Figure 1a) until the nut cracks (Figure 1b). Although, the task is quite arduous; especially for women who constitute 80% - 90% of the work force in most cashew nut factories, it is still common among rural processors in Asia and Africa (Ogunsina, 2010). Previous works on the development of shelling machines rarely considered the pre-shelling treatments to which

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cashew nuts are subjected by cottage processors. Some reports on cashew nut shelling machines include the hand operated knife cutter, pedal operated knife cutter, motorized knife cutter, box batch cracker and centrifugal cracker (Ojolo et al., 2010; Ojolo and Ogunsina, 2007; Jain and Kumar, 1997; Ajav, 1996; Thivavarvongs, 1989; Thivavarvongs et al., 1995^a; Thivavarvongs et al., 1995^b). The commonest, which perhaps was the earliest and the most popular cashew nut shelling machine is the hand or pedal operated knife cutter. Two people work on a machine; one Machine Operator who shells the nut and the Shelling Assistant who recovers the kernel. Nuts are fed manually one by one in-between two sets of blades machined to fit the contour of cashew nut (Figure 2a). When the cutting lever or pedal is pressed in one stroke, the blades come together and the pointed knife-edge hits the nut on the concave side to crack and slit it (Figure 2b). On the same stroke, the pointed knife-edge is twisted to split the nutshell into two halves along the line of symmetry; and afterwards, the nut drops into a collector beneath. The Shelling Assistant separates the shell and recovers the kernels as shelling progresses (Azam-Ali and Judge, 2001). It is expected that the kernel should remain intact and whole, but with most mechanical systems, 25% - 40% of the kernels get broken; whereas whole kernels reach 90% with the traditional method (Ajav, 1996). As a result, the cashew nut processing has been limited to a cottage industry for decades. In addition, the ridiculous price that broken-kernels attract in the international market and the labour intensive nature of the industry discourages large scale investors in most cashew nuts producing countries (Ajav, 1996).

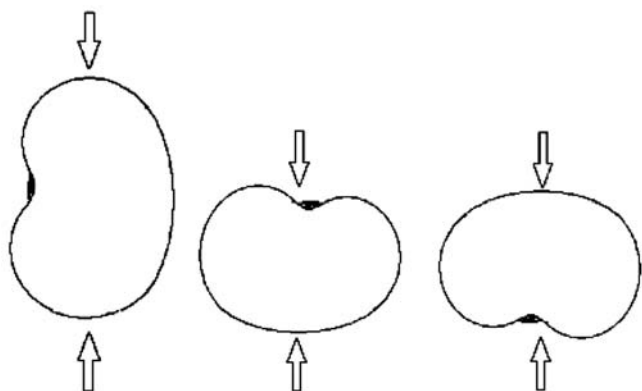


Figure 1a Axes of impact load application during traditional cashew nut shelling



Figure 1b Typical traditional cashew nut shelling in Nigeria

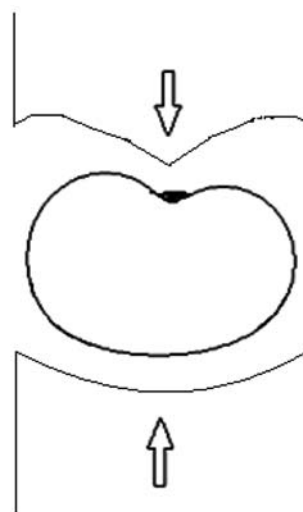


Figure 2a Placement of cashew nut in-between shelling blades of the hand operated knife-cutter



Figure 2b Cashew nut shelling using the hand operated knife-cutter in Nigeria

Although Nigeria is second among the top ten cashew nuts producers in the world (FAO, 2009), up to 90% of her present 660,000 MT annual production are exported as raw nuts to India and some other parts of Asia (Ogunsina, 2010; Ogundiran, 2011). The foremost areas

in Nigeria wherein cashew is largely cultivated include: Abia, Anambra, Cross River, Ebonyi, Enugu and Imo States in the East; Ekiti, Ogun, Ondo, Oyo and Osun States in the West; Benue, Kogi, Kwara, Nassarawa, Niger and Taraba in the Middle Belt and Kebbi and Sokoto States in the North; but, majority of export quality nuts come from the West and East. The export price of raw cashew nuts (free on board) varies between USD 1,000 and USD 1,500 MT⁻¹; whereas, processed kernels could attract triple that price if not more (Ogunsina, 2010).

Ojolo et al. (2010) remarked that the response of biomaterials to various physical treatments and conditions to which they are subjected during processing needs to be fully understood in order to maximize yield and efficiency of machines associated with various unit operations. Furthermore, an understanding of the effect of these pre-treatments on the nutritional properties of processed cashew nuts will guide processors on the choice of processing method that retains or minimizes loss of nutrients (Fagbemi, 2008). Aloba et al. (2009) investigated the physicochemical and functional properties of full fat and defatted cashew kernels. Fagbemi (2009) and Kosoko et al. (2009) found that processing method affects the chemical composition of cashew nuts significantly ($p \leq 0.05$); however, the effect of pre-shelling treatments on the crackability of cashew nuts and chemical composition of its kernels have not been reported in literatures so far. This study therefore focuses on the crackability of pre-treated cashew nuts using the hand-operated knife cutter and investigates changes on the chemical composition of cashew kernels as influenced by the pre-shelling treatments.

2 Materials and methods

2.1 Source of materials and moisture content determination

Samples for this investigation were obtained from raw cashew nuts harvested from Iwo cashew plantation, in Oyo state, Nigeria. The nuts were cleaned of all extraneous matter. Moisture content determination was carried out following the American Society of Agricultural Engineers Standard S410.1 Dec. 1997 (ASAE Standards, 1998).

2.2 Determination of nut count and kernel outturn ratio

Pre-processing quality assessment of raw cashew nuts was carried out following the method of Dahiya (2010) and Kratz (2013). This was to ensure that the samples used for this investigation conform to acceptable export quality standards. The parameters include nuts count per kg and kernel outturn ratio (KoR) which is the quantity of good kernels obtainable in pound per 80 kg bag of raw cashew nuts. A random sample of dried cashew nuts (8.3% moisture content wet basis) measuring 1 kg weight was taken and enumerated to obtain the nut count per kg. For KoR, the 1 kg nuts sample was cut longitudinally one by one into two equal halves to expose the encased kernel as split-in-peel. The split kernels were recovered from the shell and separated into four categories of quality indicators (good, spotted, immature and rotten/bad kernels) as shown in Table 1. Each category of kernels was weighed separately using a Mettler Toledo Electronic Balance (3,100 g, accuracy 0.01 g). The total weight of useful kernels, K_T was calculated by Equation (1) as:

$$K_T = K_g + \frac{1}{2}(K_{sp} + K_i) + 0(K_{br}) \quad (1)$$

where, K_T = Total weight of useful kernels, g; K_g = weight of good kernels, g; K_{sp} = weight of spotted kernels, g; K_i = weight of immature kernels, g; K_{br} = weight of bad and rotten kernels, g; and KoR is calculated by Equation (2) as:

$$KoR = 0.176 K_T \quad (2)$$

where, KoR = kernel outturn ratio, lb (80 kg)⁻¹ of cashew nuts; 0.176 = a standard factor applied for conversion into recognized unit / lb

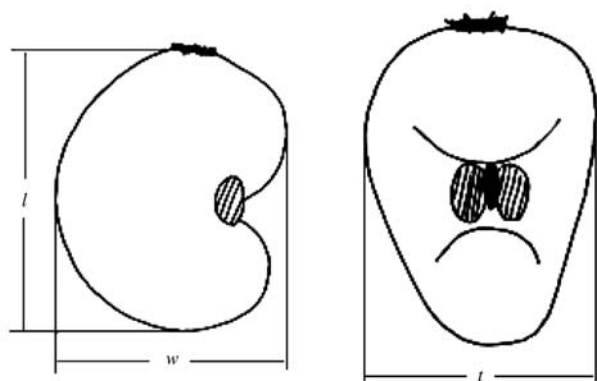
Table 1 Cashew nuts quality indicators and their distribution by weight

Category	Characteristics	*Quantity of nuts /g kg ⁻¹
Good kernels	Matured and whole good kernels which can be consumed in totality	245
Spotted kernel	Kernels bearing dark or black spots, a part of which can be consumed	10
Immature kernels	Immature, shriveled, light weight and deformed kernels, a part of which can be consumed	24
*Bad/rotten kernels	Kernels which are rotten, mouldy, which cannot be consumed	16

Note: *Values were average of three replicates.

2.3 Preparation of samples

The nuts were graded as large (26-35 mm), medium (23-25 mm) and small (18-22 mm) on the basis of their major axial dimensions shown in Figure 3 (Balasubramanian, 2001; Ogunsina and Bamgboye, 2007). Pre-shelling treatments include steam-boiling and roasting in hot cashew nut shell liquid (CNSL). For steam-boiling, 5 kg of raw cashew nuts were cooked at 7 kPa for 30 min in a cashew nut baby-boiler in three replicates; afterwards, they were cooled naturally for 18 h (Balasubramanian, 2006; Ogunsina and Bamgboye, 2013). For roasting, 5 kg of raw cashew nuts were dipped inside a bath of pre-heated CNSL (190 – 200°C) for 1.5 min (Azam-Ali and Judge, 2001; Ogunsina and Bamgboye, 2012). The roasted nuts were discharged on saw dust to mop residual coating of CNSL on the shell. Afterwards, the nuts were allowed to cool naturally for 18 h. Some samples of raw cashew nuts from the lot were used as control.



l, major axis; *w*, minor axis; and *t*, intermediate axis

Figure 3 Measurement of axial dimensions of cashew nuts

For chemical analyses, kernels that were recovered from cracked raw and pre-treated nuts were peeled, dried and kept under refrigeration till the time of use.

2.4 Assessment for selecting an expert operator for the hand-operated cashew nut knife-cutter

Five experienced operators of hand-operated cashew nut knife-cutter drawn from three major cashew nut factories in south-western Nigeria were subjected to shelling tests pro-rata using a single machine. Nuts sample drawn for this investigation were from medium grade of a particular batch of pre-treated nuts. Each operator was tasked to shell as many numbers of cashew

nuts as can be shelled within 1 min in ten repetitions. The operators were evaluated on the basis of whole kernels out-turn and number of nuts shelled per min (Equations (3) & (4) respectively).

$$K_w = \frac{W_w}{W_k} \times 100\% \quad (3)$$

where, W_w = weight of whole kernels; W_k = weight of total quantity of kernels realized after shelling.

$$\text{Number of nuts shelled/min} = \frac{\text{number of shelled nuts}}{\text{time taken in min}} \quad (4)$$

Implicitly, percent broken kernels (B_k) may be obtained as shown in Equation (5) below.

$$B_k = 100 - K_w \quad (5)$$

Data were subjected to analysis of variance using SAS (2001). The operator that had the highest whole kernels and number of nuts shelled per min was adjudged to be the most experienced; hence was selected as the expert machine operator who carried out all shelling activities during this investigation.

2.5 Crackability of pre-treated nuts

The selected expert machine operator was tasked with 1 kg of raw and pre-treated samples of cashew nuts in five replicates each. Crackability (η) was calculated based on the ratio by weight of completely shelled nuts to the total quantity of nuts fed into the machine as shown in Equation (6) (Ojolo et al., 2010; Oluwole et al., 2007^a; Oluwole et al., 2007^b).

$$\eta = \frac{W_s}{W_T} \times 100\% \quad (6)$$

where, η = crackability; W_s = weight of completely shelled nuts; W_T = weight of total quantity of nuts fed into the machine, Nuts from which there was difficulty in getting out the kernel were regarded as partially shelled/unshelled nuts and may be obtained as: $(100 - \eta)$.

2.6 Chemical analyses

The kernels obtained from pre-treated samples were analyzed for proximate composition (moisture content, crude protein, crude fat, ash and crude fibre) using the method of the Association of Official Analytical Chemists (AOAC, 2000). Carbohydrate was estimated by difference. Food energy was calculated by Atwater factors (9 fat + 4 protein + 4 carbohydrate) in kcal

(100 g)⁻¹ (Alobo et al., 2009; Ogunsina et al., 2010). Iron and calcium were determined using methods of (Alobo et al. 2009). Data were subjected to analysis of variance and means were separated by duncan multiple range tests using SAS (2001).

3 Results and discussion

3.1 Nut count and kernel outturn ratio

Raw cashew nuts for this investigation had moisture content of 8.3%, nut count of 197 nuts kg⁻¹ and KoR of 47 lb (applying Equation (1) and Equation (2) to Table 1). Moisture content of 8%-10% is generally acceptable as safe for cashew nuts and most edible kernels/oil seeds. Kernel outturn ratio is an export quality parameter which forms an economic basis to estimate or predict the income obtainable by producers or processors from a given lot of raw cashew nuts (Kratz, 2013; Dahiya, 2010). Nut count stands for the number of raw nuts per kg and merely gives an idea of the dominant grade of nuts in any particular lot; hence, it is also an important quality indicator. Balasubramanian (2006) established KoR as a very important criterion for determining the export quality in cashew nut trade. Cashew nuts with KoR≥46 lb attract premium price and yield good quality kernels when processed. Generally, KoR of cashew nuts in most producing countries varies from 40 - 56 lb per 80 kg, the higher the better the quality of kernels (Dahiya, 2010).

3.2 Selection of an operator for the hand operated knife cutter

The average number of nuts shelled per minute and the corresponding K_W for each of the assessed operators were 16 and 97.3 for shelling machine operator A; 11 and 92 for B; 14 and 93.9 for C; 9 and 82.1 for D; 17 nuts and 94.8% for E respectively (Table 2). Although, operator E produced the highest number of nuts (17) per minute, operator A with 16 nuts per minute had the highest K_W (97.3%). However, it was observed that the average number of nuts shelled per minute and the corresponding K_W by operators A and E were not significantly different. It implies that either operator A or E was capable of giving the desired results. Operator A, who had 16 nuts per minute and K_W of 97.3% was selected as the best;

because shelling efficiency demands that K_W be as high as possible. All shelling activities were carried out by operator A to maintain overall consistency.

Table 2 Shelling machine operator's assessment results

Operators Identity	Average number of nuts shelled per min	Whole kernels/%
A	16 ^a (1.2)	97.3 ^a (3.3)
B	11 ^c (0.7)	92.0 ^b (2.2)
C	14 ^b (1.1)	93.9 ^b (5.6)
D	9 ^d (1.3)	82.1 ^c (7.8)
E	17 ^a (0.7)	94.8 ^a (2.7)

Note: ^{a,b,c,d} Means on the same column with different letters are significantly different ($p<0.05$). Numbers in parenthesis are standard deviations.

3.3 Effect of pre-shelling treatments on crackability

The average crackabilities of raw, roasted and steam-boiled nuts across the grades were 76%, 100% and 99%. In Table 3, it was observed that the crackability of roasted and steam-boiled nuts was higher than that of raw nuts. Crackability was 100% for all grades of roasted nuts, which is higher than 75% by Ajav (1996); 70% by Jain and Kumar (1997) and 67% by Ojolo and Ogunsina (2007) with roasted nuts. The results showed that crackability of roasted nuts was better than that of steam-boiled nuts. The sudden temperature rise that occurs during hot-oil roasting usually case-hardens the shell, thereby making it brittle and amenable to fracture. For all pre-treatments, the crackability of medium nuts was higher than that of large and small nuts. This may be attributed to variations in the clearance that exist in-between the knife-cutting edge when the machine was actuated by the lever.

3.4 Effect of pre-shelling treatments on whole kernels out-turn

Table 4 shows the K_W of cashew nuts as influenced by pre-shelling treatments. It was observed that the pre-shelling treatments affected K_W significantly ($p<0.05$) for the three nut grades. Roasted nuts gave the highest K_W (99.6% and 99.5% for large and medium nuts respectively) except for small nuts for which K_W was 85.1%. During hot-oil roasting, the slight rise in temperature that the kernel experiences in the presence of moisture tends to parboil and toughen it thereby lessening its susceptibility to breakage and ultimately increasing K_W .

It was found that the K_W of raw nuts was the least (62%, 33.9%, and 44.7% for large medium and small respectively). The shell of raw cashew nut is naturally spongy and tough; the intra-cellular pressure that develops within the CNSL bearing cells as force was applied through the knife-edge offers some resistance to fracture when the nut was compressed. Rather than for the shell to fail and crack, the CNSL bearing cells ruptured and oozed out their contents. As more force was applied, the entire nut got compressed and the embedded kernel failed catastrophically. It is noteworthy that when raw cashew nuts are cracked, contamination by CNSL is often inevitable and this makes them unfit for consumption, which is not the case with pre-treated nuts. For all pre-treatments, K_W decreased consistently with nut grades. Overall, the K_W of large nuts was highest for all pre-treatments; implying that large nuts generally give higher K_W than small nuts.

Table 3 Crackability of cashew nuts on the basis of nut grade and pre-shelling treatments

Nut Grades /mm	Crackability of pre-treated nuts/%		
	Raw	Roasted	Steam-boiled
Large (26-35)	72 (28)	100 (0)	100 (0)
Medium (23-25)	78 (22)	100 (0)	100 (0)
Small (18-22)	77 (23)	100 (0)	96 (4)
Average across the nut grades	76 (24)	100 (0)	99 (1)

Note: Percentages of unshelled/partially shelled nuts are in parenthesis.

Table 4 Whole kernels of pre-treated cashew nuts

Nut grades	$K_W (B_k)$		
	Raw	Steam-boiled	Roasted
Large (26-35)	62.0 ^c (38)	91.7 ^b (8.3)	99.6 ^a (0.4)
Medium (23-25)	33.9 ^c (66.1)	73.7 ^b (26.3)	99.5 ^a (0.5)
Small (18-22)	44.7 ^c (55.3)	87.0 ^a (13.0)	85.1 ^b (14.9)

Note: ^{a,b,c}Means on the same row with different letters are significantly different ($p < 0.05$). K_w = whole kernels; B_k = broken kernels.

3.5 Effect of pre-shelling treatments on the chemical composition cashew kernel

The chemical composition of cashew kernels as affected by pre-shelling treatment is presented in Table 5. For raw, roasted and steam-boiled kernels, crude protein was 21.32%, 22.24% and 23.07%; while crude fat was 42.19% 41.06% and 41.62%. These results agree with the report of Aloblo *et al* (2009), and Fagbemi (2009) who

had earlier worked on the proximate and nutritional properties of cashew kernels. The pre-shelling treatment showed no significant difference in the chemical composition and energy of cashew kernels but for crude fibre and carbohydrates wherein the difference was significant ($p < 0.05$). The expected trend shown by moisture content indicates slight increase from 5.16% in raw to 5.30% in steam-boiled nuts and a decrease to 4.65% in roasted nuts.

Table 5 Chemical composition of pre-treated cashew kernels

Chemical components	Pre-treatment		
	Raw	Hot-oil roasted	Steam boiled
Protein/%	21.32 ^a (0.80)	22.24 ^a (1.31)	23.07 ^a (1.01)
Crude Fibre/%	4.35 ^b (1.41)	5.13 ^a (0.11)	4.51 ^b (0.05)
Crude Fat/%	42.19 ^a (0.4)	41.06 ^a (0.96)	41.62 ^a (0.32)
Ash/%	2.79 ^a (0.38)	2.71 ^a (0.29)	2.62 ^b (0.19)
Moisture Content/%	5.16 ^a (0.85)	4.65 ^b (0.14)	5.30 ^a (0.02)
CHO/%	24.19 ^a (0.44)	24.21 ^a (0.89)	22.88 ^b (0.63)
Iron/mg (100 g) ⁻¹	5.61 ^a (0.02)	5.52 ^a (0.04)	5.12 ^b (0.02)
Calcium/mg (100 g) ⁻¹	52.1 ^a (0.82)	50.6 ^a (1.23)	51.2 ^a (0.90)
Energy/kcal (100 g) ⁻¹	561.75 ^a (0.88)	555.34 ^a (0.1)	558.38 ^a (0.24)

Note: ^{a,b}Means on the same row with different letters are significantly different ($p < 0.05$). Numbers in parenthesis are standard deviations.

The crude protein content in cashew kernels compares favourably with that of almond, 20.8%; linseed, 20.3%; mustard, 20% and groundnut, 26.25% (Gopalan *et al.*, 2007; Nair, 2010). Hazel nut, macadamia and almond have lesser protein content with 12.7%, 9.2% and 15.6% respectively; but the crude fat content of cashew kernels (41.06% - 42.19%) makes it stand out among other edible kernels. Almond, hazelnut, macadamia, walnut, pistachio and sunflower have 59.9%, 60.9%, 64.5%, 78.2%, 53.5% and 52.1% respectively; whereas, groundnut, mustard, nigerseed and linseed have 39.8%, 39.7%, 39%, 37.1% respectively (Gopalan *et al.*, 2007; Nair, 2010). Besides, the high oleic acid content in cashew kernel fat and its other nutritional benefits make it a prized food snack among peers. The relatively short duration of pre-treatment during steam boiling focuses essentially on making the shell brittle enough to crack without affecting the encased kernel. It leaves no chance to leaching of nutrients as often associated with cooking of foods. Congruently, the interaction of CNSL with the shell during hot-oil roasting is limited by the semi-impervious

nature of the endocarp layer which protects the kernel in the internal cavity. The kernel is therefore able to retain originality in its chemical composition since there is virtually no interaction between the roasting oil and the kernel. This may be the reason why the differences in crude protein due to the pre-treatments were not significant. The slightly significant ($p < 0.05$) decrease in the ash content of the roasted nuts reflected in the iron and calcium contents. In comparison with groundnut, sunflower and linseed, cashew kernel is higher in iron and low in calcium contents.

4 Conclusions

The crackability of pre-treated cashew nuts and chemical composition of cashew kernels have been studied, using the hand-operated knife cutter, considering three nut grades (large, medium and small) and two methods of pre-shelling treatments (hot-oil roasting and steam-boiling). The following conclusions may be drawn:

1) Pre-treated nuts generally crack more easily than raw nuts. The crackability of roasted nuts was higher than that of steam-boiled nuts and pre-shelling treatment affected K_w significantly ($p < 0.05$).

2) Roasted nuts exhibited the highest K_w (99.6% and 99.5% for large and medium nuts respectively) except for small nuts for which K_w was 85.1%. It was found that the K_w of raw nuts: 62%, 33.9%, and 44.7% for large medium and small respectively were the least for all nut grades.

3) The K_w of large nuts was highest for all

pre-treatments; implying that large nuts generally give higher K_w than medium and small nuts.

4) The pre-treatment showed no significant difference in the chemical composition and energy of cashew kernels but for crude fibre and carbohydrates wherein the difference was significant ($p < 0.05$).

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List of abbreviations

CNSL = cashew nut shell liquid

η = crackability, %

W_s = weight of completely shelled nuts, g

W_T = weight of total quantity of nuts fed into the machine, g

W_w = weight of whole kernels, g

W_k = weight of total quantity of kernels realized after shelling, g

K_w = whole kernels out-turn, %

B_k = percent broken kernels, %

K_T = Total weight of useful kernels, g

K_g = weight of good kernels, g

K_{sp} = weight of spotted kernels, g

K_i = weight of immature kernels, g

KoR = kernel outturn ratio / lb (80 kg)⁻¹ of cashew nuts

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